Bulletin No. 3.

1899.

Experiment Station

THE TUSKEGEE NORMAL AND INDUSTRIAL INSTITUTE,

Tuskegee, Alabama.

Fertilizer Experiments on Cotton.

G. W. CARVER, Director.

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FERTILIZER EXPERIMENTS ON COTTON.

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PROF. G. W. CARVER, DIRECTOR.

The cotton fertilizer experiments made in 1898 are a continuation of a series of fertilizer soil tests commenced in 1897. The soil of the experimental field, a part of the station farm, is a light and sandy upland, with yellow clay subsoil.

The soil selected is excelentlly adapted for experimental purposes, having formed part of an old field which has been planted by the wasteful methods of the tenant system, year after year, for a long period. The soil was thoroughly "worn out" as to its supply of fertilizing substances, nitrogen potash, and phosphoric acid, and was also in very bad physical condition. Its humus had long since been totally worked out and the top soil was very thin and with very little power to retain moisture. Even cow-peas failed to make a fair growth, on this soil before these experiments were begun, which is a pretty sure sign of a soil practically exhausted.

In 1897, the soil was first broken for fertilizer tests, as detailed somewhat at length in Bulletin No. 3 of this station. The plows were worked to a depth of eight to nine inches, and the soil was thoroughly pulverized to that depth until it was all even and mellow. Plots were then laid off, one-tenth of an acre each in size, with foot-paths, four feet wide, surrounding them. There are sixteen plots in all, divided into two sections of eight plots each. The two sections were treated in every respect precisely the same, except that one section was given in 1897 an application of burned lime at the rate of 2000 pounds per acre, in addition to the fertilizers used, while the other section was not limed. The object of this treatment was to determine the value of lime on the unfertilized soil, and also its effect in connection with chemical fertilizers.

"Chemical fertilizers" require a word of explanation. When soils began to "wear out" through planting year after year, without the use of any form of manures, in some way it was discovered that farmyard manures brought back the strength of the soil. As it is not practical to profitably return to the soil all that is grown on it, else there would be no sale crop, in the course of time it was found that the soil failed even with the use of farmyard manures. This failure was largely due to the fact that not enough manures were used, because not enough could be made on the average plantation to supply the drains on the soil. Out of the deficiency grew a thorough scientific study of the nature of manures. It was learned after many year's investigation, that manures were chiefly valuable as plant food only as they contained nitrogen, potash, and phosphoric acid. These three substances, commonly called plant food ingredients, are all equally necessary to plant growth. No plant can thrive without a bountiful supply, not of any one, or of any two, but of all three of these plant food ingredients.

Farmyard manures contain all three of the plant food ingredients, but in very small quantities. A ton of average farmyard manure contains about ten pounds of nitrogen, ten pounds of potash, and six pounds of phosphoric acid. These three substances, which are of so much importance to planters are found in many different forms; often having the same general appearance as common table salt. Such materials are usually called "commercial fertilizers." The nitrogen, potash or phosphoric acid they contain is just as valuable for plant food as the same substances in farmyard manure, and enormous quantities of these commercial fertilizers are used every year. These chemical manures are much stronger than farmyard manure. For example, 20 pounds of muriate of potash contain as much actual potash as a ton of average farmyard manure; but, it contains potash only and other chemical manures must be used with it to supply the necessary nitrogen and phosphoric acid.

In these experiments three kinds of chemical manures were used, and the selection was made to include those materials most generally found in the fertilizer market. These materials were as follows:— Supplying Nitrogen: Nirate of Soda, containing 16 per cent Nitrogen or 320 pounds to the ton.

Supplying Potash: Muriate of potash, containing 50 per cent potash or 1000 pounds to the ton, also sulphate of potash supplying the same quantity of actual potash per ton.

Supplying Phosphoric Acid: Acid Phosphate, containing 14 per cent available or 280 pounds to the ton.

From the above it will be seen that the materials used supplied all three of the necessary plant food ingredients. In the

following pages of this Report, the expressions "nitrate," "potash," and "phosphate" must be understood to refer to the above substances, in the order in which they are written.

In 1897 the test field was planted to Sweet potatoes, and the fertilizers used as well as the crops returned were given in full in Bulletin No. 2, this Station. The crop was a partial failure on account of severe drouth; and, as there is substantially very little loss of either potash or phosphate through the leaching of rain water, it was decided not to make further applications of these fertilizers in 1898 With nitrate, however, the conditions are different. Nirate of soda is very soluble in water and is pretty thoroughly washed out of the soil during the winter rains. The following table shows the fertilizer applications made in the Sweet Potato experiments in 1897.

TABLE 1, showing the pounds per plot, and per acre, of fertilizer applied to the unlimed section, in the sweet potato experiment, in 1897.

PLOTS.	FERTILIZER APPLIED.	AMOUNT PER PLOT ONE-TENTH ACRE.	EQUIVALENT PER ACRE.
No. 1	Unfertilized		
No. 2	Acid phosphate, Muriate of Potash,	60 lbs. 12 "	600 lbs. 120 "
No. 3	Muriate of Potash, Nitrate of Soda,	12 lbs. 20 "	120 lbs. 200 "
No. 4	Acid phosphate, Nirate of Soda,	60 lbs. 20 "	600 lbs. 200 "
No. 5	Acid phosphate. Nitrate of Soda. Muriate of Potash.	60 lbs. 20 " 12 "	600 lbs. 200 " 120 "
No. 6	Acid phosphate. Nitrate of Soda. Muriate of Potash.	60 lbs. 20 " 24 "	600 lbs. 200 " 240 "
No. 7	Acid Phosphate. Nitrate of Soda. Sulphate of Potash.	60 lbs. 20 " 24 "	600 lbs. 200 " 240 "
No. 8	Unfertilized.	———	———

The limed section consists of eight plots similarly arranged, and fertilized precisely in the same manner; each plot received, however, in addition 200 pounds of lime per plot, equal to an application per acre of 2000 pounds. The unfertilized as well as the fertilized plots received the lime treatment.

The cultivation of all these plots was precisely the same. The potash and phosphate were applied immediately after plowing, broadcasted over the whole area of the plots, and thoroughly harrowed in. The nitrate was applied much latter. The plants were set late, and the setting was followed by seventeen days without rain. The weather was unfavorable throughout the season, and the yield was consequently light though the fertilized plots gave much higher returns than the unfertilized plots.

In 1898 the same plots were used for the cotton experiments. Both sections, limed and unlimed, received in 1898 the same quantity of nitrate of soda as in 1897, but no other fertilizer and no lime. The following table gives the exact application of fertilizer per plot in 1898, both sections being treated precisely alike.

TABLE II. Showing after effects of mineral fertilizers Phosphoric Acid and Potash on limed and unlimed sections of the 1898 experiment.

PLOT No.	FERTILIZER APPLIED IN 1898 PER ACRE.	FERTILIZER APPLIED IN 1899 PER ACRE.
1.	Nothing.	Nothing.
2.	600 lbs. Acid Phosphate. 120 " Muriate of Potash.	Nothing.
3.	120 lbs. Muriate of Potash.	200 lbs. Nitrate of Soda.
4.	600 lbs. Acid Phosphate.	200 lbs. Nitrate of Soda.
5.	600 lbs. Acid Phosphate. 120 " Muriate of Potash.	200 lbs. Nitrate of Soda.
6.	600 lbs. Acid Phosphate. 240 " Muriate of Potash.	200 lbs. Nitrate of Soda.
7.	600 lbs. Acid Phosphate. 240 " Sulphate of Potash.	200 lbs. Nitrate of Soda.
8.	Nothing.	Nothing.

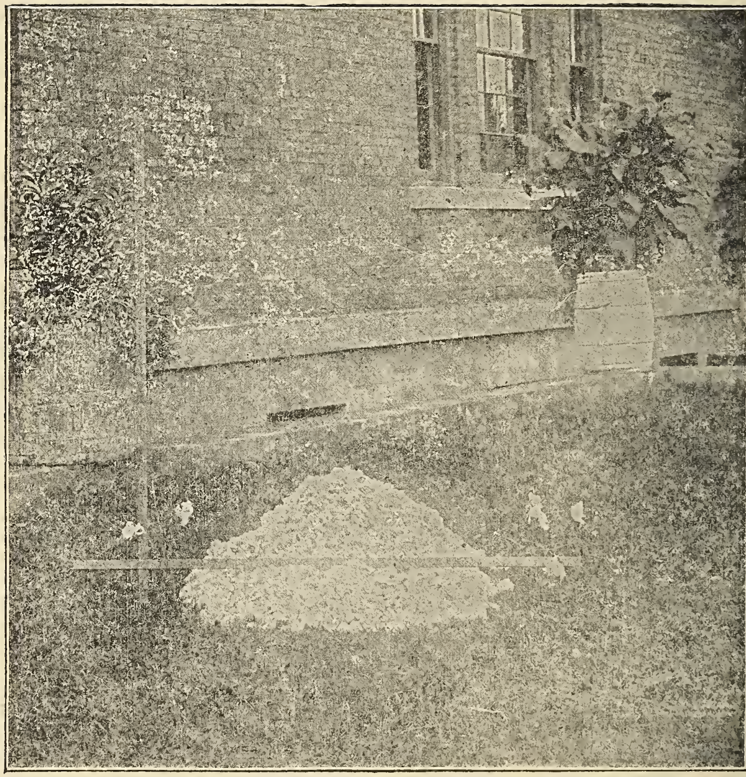
The cotton, common mixed in variety, was planted May 5, in rows four feet apart, the plants thinned to twelve inches apart in the rows. There were fifteen rows to the plot. The nitrate of soda was applied, one half on May 20, the remainder on June 2nd.

The following table gives the yield of seed-cotton per acre, ——that is, ten times the yields per plot——with the gains made by the fertilized over the unfertilized plots. The plots fertilized in 1897 are called the fertilized plots, as the experiment of 1898 was wholly dependent on the experiment of 1897 for potash and phosphoric acid; two very necessary fertilizer ingredients for cotton.

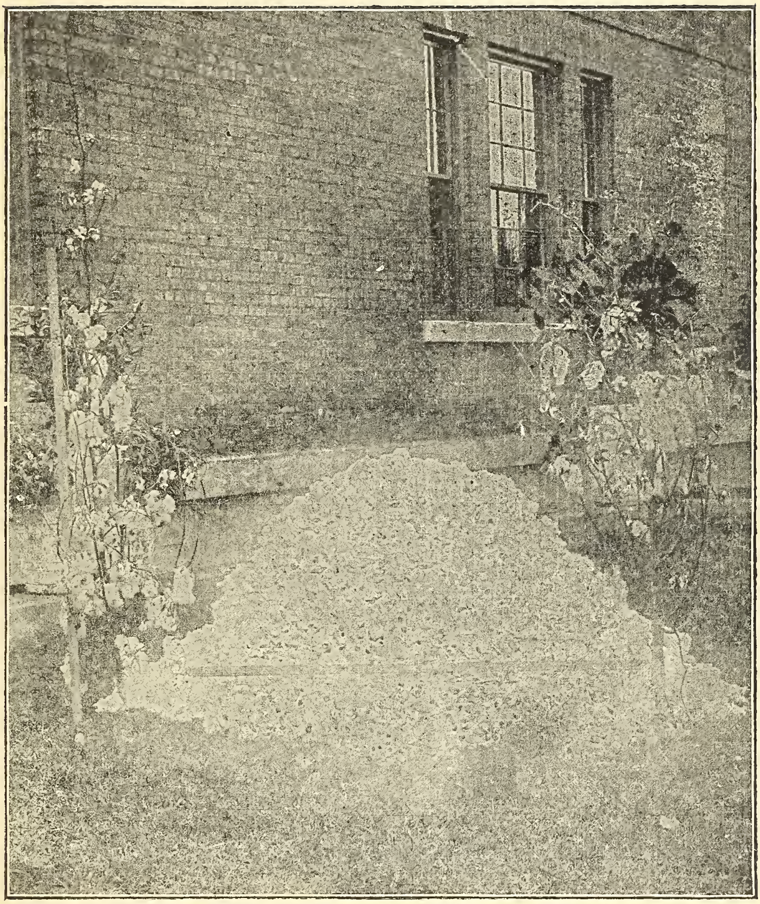
UNLIMED SECTION.

TABLE III, showing the yield of seed cotton per acre, and the increased yield due to the use of fertilizers.

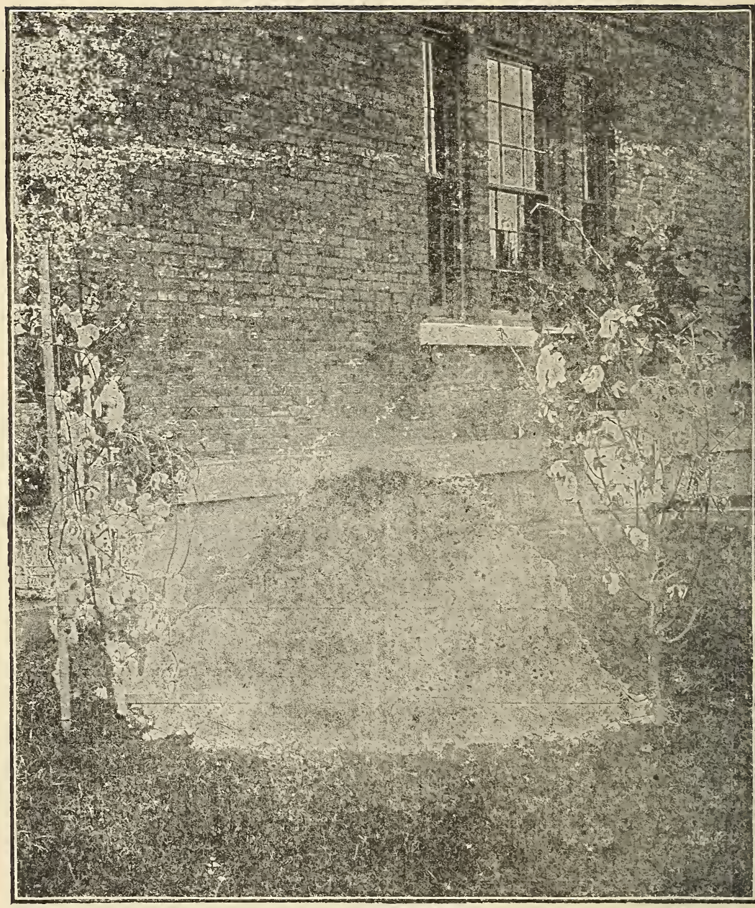
PLOTS.	SEED COTTON.	INCREASED YIELD.
1	240 lbs.	———
2	1590 lbs.	1350 lbs.
3	1800 lbs.	1560 lbs.
4	880 lbs.	640 lbs.
5	1690 lbs.	1450 lbs.
6	1789 lbs.	1549 lbs.
7	1792 lbs.	1552
8	240 lbs.	———



Yield from plot 1, No fertilizer, at the rate of 240 lbs. per acre of seed cotton.



Yield from plot 3, treated with muriate of potash 12 pounds and nitrate of Soda 20 Pounds, at the rate of **1800** lbs. seed cotton per acre.



Yield from plot 6, treated with nitrate of soda 20 pounds: muriate of potash 24 pounds; acid phosphate 60 pounds, at the rate of 1,789 lbs. seed cotton per acre—the fertilizer used on this plot contains 3 per cent nitrogen, 8 per cent phosphoric acid and 12 per cent potash.

LIMED SECTION.

PLOTS.	SEED COTTON.	INCREASED YIELD.
1	510 lbs.	————
2	1600 lbs.	1090 lbs.
3	1849 lbs.	1339 lbs.
4	860 lbs.	350 lbs.
5	1680 lbs.	1170 lbs.
6	1800 lbs.	1290 lbs.
7	1790 lbs.	1280 lbs.
8	510 lbs.	————

The results are very striking when the condition of the soil previous to the beginning of these experiments is considered. Though but one application of potash and phosphoric acid was made for the two years, the yield on the fertilized plots the second year gave returns over six times that of the unfertilized soil.

It is not practicable to reduce these experiments to dollars and cents, as we have no data on which to base an estimate of the quantity of fertilizer applied in 1897, which should be charged to 1898. The lime, also, should not be charged against any one year's work only. As the Station gains experience through repeated experiments, we will be able to more definitely estimate the dollars and cents value of the experiments. At this stage we must more properly confine our work to an examination into the relative crop-making power of the different combinations of fertilizers. For example, on the unlimed section, the unfertilized soil, plots 1 and 8, gave a yield of 240 pounds of seed cotton per acre, while the soil treated with "complete" fertilizer, plots 5, 6 and 7, gave an average return of 1757 pounds.

Among the questions which naturally suggest themselves are: the effect of nitrogen fertilization, potash fertilization, phosphoric acid fertilization, influence of lime, and results of incomplete and complete manuring. The cotton experiments give

useful information bearing on these points, and information, too, which may be used to advantage by planters working soils similar to those of the Station farm.

Nitrogen as plant food has as its chief function the development of leaf and stalk; if used in great excess the development of blossoms is retarded though the stalk and leaf make a rank growth. The influence of nitrogen fertilizer in the cotton experiment is shown by the results on plots 2 and 5, as follows:

PLOTS.	FERTILIZER.	INCREASED YIELD.
2	Potash and Phosphate.	1350 lbs.
5	Nitrate, Potash and Phosphate.	1450 lbs.
	Increase.	100

Plots 2 and 5 both received potash and phosphoric acid, and plot 5 also received nitrate of soda. The difference in yield between plots 2 and 5 should show how much the crop-making power of phosphoric acid and potash was aided by adding nitrate of soda; this difference is 100 pounds of seed cotton which appears to represent the crop-making power of nitrate of soda, on this particular soil.

As a rule nitrogen makes a much better showing, and a word of explanation will not be out of place. As previously stated the tendency of nitrogen is to wash away and leach through the soil.

The deep plowing and thorough pulverization of the land in 1897 brought to the surface, and rendered available enough nitrogen that had sunken below the agricultural depth and had otherwise become non-available by reasons of the poor physical condition of the soil, to make a good yield of sweet potatoes. The same applies to cotton and all crops and is one of the many strong arguments in favor of deep plowing.

Many dollars worth of fertilizers can be saved yearly aside from a paying increase in yield per acre by the proper rotation of crops, and deep fall and spring plowing.

Similarly compared, plots 4 and 5 indicate the value of potash fertilizer, as follows:

PLOTS.	FERTILIZER.	INCREASED YIELD.
4	Phosphate and Nitrate of Soda.	640 lbs.
5	Potash, Nitrate, and Phosphate.	1450 "
	Increase.	810 "

As the special function of potash as a plant food is to develop the woody part of stems and the pulp of fruit as well as the lint of cotton, it was expected that this fertilizer would make a high showing. As a crop maker it appears to have over eight times the value of nitrate of soda.

The effect of phosphoric acid is shown by the results on plots 3 and 5, as follows:

PLOTS,	FERTILIZER.	INCREASED YIELD.
3	Potash and Nirate.	1520 lbs.
5	Phosphate, Nitrate, and Potash.	1450 "
	Decrease.	700

From which data it seems that phosphoric acid failed to effect useful results with cotton on this soil.

As the unfertilized soil will return 240 pounds of seed cotton per acre, the addition of nitrate of soda alone increases the yield to 340 pounds, potash alone would probably increase the yield to (810 plus 240) 1050 pounds, while phosphoric acid does not increase the yield. It would seem from this that the soil contains naturally a fair supply of phosphoric acid available as plant food for cotton. The practical deduction to be drawn from this is that for cotton on light sandy soils with yellow clay subsoil, potash and nitrogen are the most important ferteilizer ingredients.

"Complete" fertilizers indicate a mixture, or the use, of all three of the chief fertilizer ingredients. "Incomplete" fertilizers mean the use of one or at most only two of the fertilizer ingredients. In these experiments, potash and nitrate of soda gave as good results as a complete fertilizer, plots 3 and 5 while potash and phosphoric acid as well as phosphoric acid and nitrate gave returns below the completely fertilized plots.

Two forms of potash were compared: Sulphate and Muriate. The results were;

PLOTS.	FORM OF POTASH.	INCREASED YIELD.
6	Muriate of Potash.	1520 lbs.
7	Sulphate of Potash.	1552 "

The result indicate a slight gain, 32 pounds, in favor of sulphate of Potash but the difference is not sufficiently great to prove significant.

As potash makes the most important showing, the effect of increasing the potash becomes of interest. Plot 5 received 120 pounds of muriate of potash per acre while plot 6 received just twice as much. The results were;

PLOTS.	POTASH.	INCREASED YIELD.
5	120 lbs.	1450 lbs.
6	240 lbs.	1552 lbs.

The gain due to doubling the potash, 102 pounds per acre, is further evidence that such soils are deficient in potosh.

EFFECT OF LIME.

The special function of lime is to improve the mechanical condition of soils. It loosens heavy clay soils as well as compacts light sandy soils. Lime also aids in decomposing vegetable matter in soils, thus hastening the availability of such plant food as may be contained therein. It must be understood that lime of itself is not plant food, but it aids in rendering plant food naturally in the soil available to growing plants. As the soil on which these experiments were conducted was in poor mechanical condition, liming should have served a useful purpose. The effect of lime is shown in the following table:

PLOTS.	YIELD UNLIMED.	LIMED YIELD.	GAIN DUE TO LIME.
1	240 lbs.	510 lbs.	270 lbs.
2	1590 lbs.	1600 lbs.	10 lbs.
3	1800 lbs.	1849 lbs.	49 lbs.
4	880 lbs.	860 lbs.	-20 lbs.
5	1690 lbs.	1680 lbs.	-10 lbs.
6	1789 lbs.	1800 lbs.	11 lbs.
7	1792 lbs.	1790 lbs.	-2 lbs.
8	240 lbs.	510 lbs,	270 lbs.

Lime seems to have served usefully in this experiment on the unfertilized soil, but was with out effect when the soil was fertilized. This is quite in accord with the theory of the use of lime. It acts in a measure as a soil stimulant, and while it frequently increases growth, it does so at the expense of the stores of fertility in the soil.

The cost of making a crop on the Station land was about $14.00 per acre, perhaps somewhat less than the average on the adjacent plantations, due to the use of labor saving devices. Estimating one-third the yield as lint and valuing same at $4.50 per 100 pounds, it is evident that the unfertilized soil did not pay cost of making the crop; in fact, the loss wos about $10.40 per acre.

For the purpose of comparison, the problem of how much potash and phosphate the cotton drew from the Sweet Potato experiment in 1897, may be disregarded; the returns on all plots may be compared, in the form of the value of the crop on each plot irrespective of the fertilizer cost. This merely shows the gain of the fertilized plot over those unfertilized, but if a planter knows about how much fertilizer may be expected to increase the yield of his soil, he can very easily form an estimate of the profitableness of fertilizers in his individual case.

The following table shows the value of the crop per acre based on a lint weight equal to one-third the seed cotton, and $4.50 per hundred for lint. Only the unlimed section is used for comparison in this case.

TABLE III, Showing value of crop per acre—unlimed section—gain over unfertilized plots and the precentage of this gain compared with the results on plots 1 and 8.

PLOTS.	FERTILIZER.	CROP VALUE PER ACRE.	GAIN PER ACRE.	PER CENT.
1	Unfertilized.	$3,60		
2	Phosphate, 60 lbs. Muriate Potash, 12 lbs.	23.85	$20.25	563.
3	Muriate Potash, 12 lbs. Nitrate, 20 "	27.00	23.40	650.
4	Phosphate, 60 lbs. Nitrate, 20 "	13.19	9.59	266.
5	Phosphate, 60 lbs. Muriate Potash, 12 " Nitrate, 20 "	25.34	21.74	604.
6	Nitrate, 20 lbs. Muriate Potash, 24 " Phosphate, 60 "	26.82	23.22	645.
7	Nitrate, 20 lbs. Sulphate Potash 24 " Phosphate, 60 "	26.87	23.27	646.
8	Unfertilized.	3.60		

It is quite evident from the above table that fertilizers may be used profitably on cotton. Every combination of fertilizer chemicals has given a clear margin of profit, excepting perhaps plot 4, which received only nitrate and phosphates,